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PILOT-SCALE STUDY ON BATAC JIG WASHING OF WAPITI COAL GULF CANADA RESOURCES LTD.

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PILOT-SCALE STUDY ON BATAC JIG WASHING OF WAPITI COAL - GULF CANADA RESOURCES LTD.

by

M.W. Mikhail*, I.S. Parsons** and O.E. Humeniuk***

ABSTRACT

A 12 tonne raw coal sample of thermal coal from Wapiti was submitted by Gulf Canada Resources Inc. for pilot plant Batac jig evaluation. The objectives of the program were to produce clean coal with a minimum of 23730 kJ/kg heat value and outline a flowsheet to achieve that.

Pilot plants tests included Batac jig circuit with recirculating middlings for the 12.7 x 0.6 mm size fraction and two stage water-only cyclone for the minus 0.6 mm. Results indicate a recovery of 69.9% by mass at 19.6% ash (equivalent to 24392 kJ/kg) with 80.4% thermal recovery. Projection from the washing tests using the Batac jig for 12.7 x 0.6 mm shows a thermal recovery of 96.3% can be achieved to produce clean coal with 21.4% ash (db) which is equivalent to 23730 kJ/kg.

Based on coal characteristics and pilot plant testing, a flowsheet is proposed to dry screen the minus 10 mm and clean the plus 10 mm in a heavy medium bath. The presence of relatively high amounts of near density material between 1.6 and 1.8 relative densities favours the heavy media bath over the Batac jig. A blend of raw minus 10 mm and cleaned plus 10 mm fractions is expected to achieve about 95% thermal recovery and produce a blend with 23730 kJ/kg.

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ÉTUDE À L'ÉCHELLE-PILOTE, PAR LAVAGE SUR CRIBLE BATAC, DE CHARBON PROVENANT DE WAPITI, PRÉSENTÉ POUR ÉVALUATION PAR GULF CANADA RESOURCES LTD.

par

M.W. Mikhail*, I.S. Parsons** et O.E. Humeniuk***

RÉSUMÉ

Un échantillon constitué de douze tonnes de charbon thermique provenant de Wapiti a été présenté par Gulf Canada Resources, pour fins d'évaluation au moyen de l'unité de lavage sur crible Batac. Le programme avait pour objectifs la production d'un charbon propre ayant un pouvoir calorifique nominal de 23 730 kJ/kg et l'élaboration d'un schéma de fonctionnement pour arriver à ces fins.

Les essais à l'unité-pilote comprenaient un circuit de lavage sur crible Batac et la recirculation de mixtes en vue d'obtenir une particule de 12,7 X 0,6 mm. On a utilisé un hydrocyclone à deux étapes de lavage pour obtenir la particule de moins de 0,6 mm. Les résultats indiquent un taux de récupération de 69,9 % (poids en pourcentage), une teneur en cendre de 19,6 % (équivalent de 24 392 kJ/kg) et un taux de récupération thermique de 80,4 % . Les prévisions établies à partir des essais de lavage sur crible Batac indiquent que le taux de récupération thermique des particules de 12,7 X 0,6 mm peut atteindre 96,3 % , ce qui permet d'obtenir un charbon propre dont le contenu en cendre est de 21,4 % (db), équivalant à 23 730 kJ/kg.

À partir des caractéristiques du charbon et des essais de lavage à l'unité-pilote, on propose un schéma de fonctionnement pour le criblage par voie sèche des particules de moins de 10 mm et le lavage en milieu dense des particules de plus de 10 mm. La présence d'une quantité importante de

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substances presque opaques dont les densités relatives étaient de 1,6 et 1,8 démontre que l'épuration en milieu dense est préférable au lavage sur crible Batac. En utilisant un mélange de particules non lavées, d'une granulométrie de moins de 10 mm, et de particules propres de plus de 10 mm, il devrait être possible d'obtenir un taux de récupération thermique d'environ 95 % et de produire un mélange ayant un pouvoir calorifique de 23 730 kJ/kg.

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INTRODUCTION

A pilot plant scale Batac jig was recently installed at the Coal Research Laboratory (CRL) pilot plant facilities in Edmonton. The Batac jig project is partly financed by several coal companies to evaluate the Batac jig in washing their coals. The project is intended to generate test data and experience on Canadian coals to reduce risks in designing new plants and modifying existing ones.

In Germany, the use of the Batac jig in washing both coarse and fine fractions is common in newly designed plants and is gradually replacing the heavy medium bath in existing plants. The common practice is to use the jig to wash the coarse (plus 10 mm) and fine (10 x 0.5 mm) fractions separately. The increased application of the Batac jig both in Germany and other countries is claimed to be due to the following advantages (1):

1. Large tonnages can be treated, simplify plant size and layout and reduce capital cost

2. Because of its precise controls, the jig is able to respond quickly to changes in either feed rate or coal characteristics

3. Estimated operating cost is 40% less than for the heavy medium systems

4. Performance compares favourably with heavy medium systems for cutpoints above 1.55 for coals with limited amount of near density material.

Generally, Canadian coals are not so easy to wash as German coals. The Batac jig offers certain advantages, but an understanding of how it behaves with Canadian Coals is not clear. The testing program on different Canadian coals can benefit industry by verifying reported claims and generating data for commercial plant design.

A bulk sample weighing approximately 12 tonnes was collected from Wapiti adit #1 and delivered to the CRL. This report represents results and

discussions of washing tests, evaluates and compares the Batac jig performance with other systems, and the feasibility of washing Wapiti coal to meet required objectives.

COAL CHARACTERISTICS

Based on the analysis in Table 1 and according to the ASTM system of classification, Wapiti coal can be ranked in the bituminous C category. The analysis given in Table 1 is a split of the bulk sample (approx. 12 tonne and considered to represent the bulk sample received for washing tests).

SIZE DISTRIBUTION

The sample received was relatively coarse with less than 10.7 per cent by mass finer than 0.6 mm size. Tables 2 and 3 show the screen analyses of the raw coal before and after being crushed to minus 12.7 mm respectively. The analyses indicate a trend similar to most western Canadian coals, i.e. decrease in ash contents with decrease in particle size as relatively lower ash particles tend to be more friable than the higher ash ones. However, the ash contents of the fine fractions are not as low as can be expected and that is probably caused by the presence of relatively soft high ash particles.

HEAT VALUE/ASH CONTENT

Thermal content can be reliably expressed as a linear function of the ash content of a given coal. The ash and thermal contents of different densities and size fractions were used to establish the following relationship (Appendix A).

$$kJ/kg(db) = 31597 - 367.6*Ash$$

where ash is expressed in per cent.

A minimum heat value of 23730 kJ/kg (10200 Btu/lb) is required for the clean coal product. This corresponds to 21.4% ash (db) and equivalent to 19% ash as received basis (11.35% moisture a.r.b.).

WASHABILITY

Washability analyses were carried on two fractions with top size ranges of 50 mm and 12.7 mm. The coarse size range washabilities (minus 50 mm) would more or less represent the raw coal that might be washed in a commercial size plant. The minus 12.7 mm washabilities represent the raw coal being fed to the pilot plant.

Washability curves of the 50 x 0.6 mm in Figure 1 (data in Table 4) indicate low theoretical recovery at a 15% ash or less. However, at 21.4% ash (23730 kJ/kg) a high theoretical recovery of 84% by mass at 1.86 cut point (dp) is indicated. For the 0.6 x 0.15 mm fraction, washability data (Table 5 and Figure 2) indicate no washing is required to achieve a heat value of or above 23730 kJ/kg (above 10200 BTU/lb) as indicated earlier. Washability curves of the 12.7 x 0.6 mm (after reducing the top size from 50 to 12.7 mm) indicate slight change in coal washability that reflect an increased recovery from 84% (for the 50 x 0.6 mm) to 87% by mass (Table 6 and Figure 3). However the total ash of the 0.6 mm x 0.15 mm is increased (Table 7 and Figure 4) due to possible presence of soft high ash material that easily is reduced in size during crushing and reports with the 0.6 x 0.15 mm fraction.

The overall effect of crushing the ROM from a top size of 50 mm to 12.7 mm is examined. Figure 5 indicates no significant improvement in coal washability as a result of crushing. The observed slight difference could be attributed to errors in splitting the samples and analysis rather than to change in coal washability as there is a difference of approximately 1% ash in the total ash of the two samples. As a result of the insignificant difference, it would be beneficial to wash the coal as coarse as possible and remove the finer fractions (minus 2 mm or larger, most likely 10 mm) before washing and blend with the coarse cleaned coal. This would simplify plant design and save on costly dewatering and drying circuits.

COAL FRIABILITY

Estimation of the coal friability is essential at an early stage of development for preparation plant design, dust control and handling of coal. Several direct and indirect methods are available to predict coal degradation. The Australian wet attrition test is used to predict the amount of degradation (2). The test treats raw coal on a laboratory scale under

conditions simulating commercial wash plant treatment. A 50 kg sample of raw coal is tumbled with 150 kg of water along with a standard number of 50 mm steel cubes in a steel drum of 200 L capacity at 20 rpm. Tumbling duration range between 1 to 7 min. to represent the retention time in wash plants. Size distributions before and after the attrition test are compared to determine the degree of size degradation. The actual degradation during processing in the pilot plant is determined by comparing reconstituted feed (clean coal + coarse reject + fine reject) and raw feed size consist. Also the ΔP index measurement is used to predict the amount of minus 0.6 mm in the future run-of-mine. Figure 6 shows size distribution before and after attrition in the 50 mm x 0. The ΔP index value measured on four raw coal samples is 8.5.

PERFORMANCE PREDICTION

In practice, recoveries would be lower than the theoretical recoveries because of errors of separation inherent in any process. The effect of these errors of separation can be seen from the predicted washing results in Figure 7 for the plus 0.6 mm fraction. These predictions cover the dp range of 1.50 to 1.90 relative densities. The probable error (r) is a parameter used in prediction calculations to convert the theoretical results (from washability curves) into the practical results which one could expect from the actual process. The prediction curves are for heavy medium cyclone (HMC), Baum jig and water-only-cyclone (WOC). These predictions are necessary to determine pilot plant flowsheet and setting of equipment parameters to achieve the cleaning objectives. From the curves (Fig. 7), it appears likely in practice that a washed coal with 21.4% ash (23730 kJ/kg) would be obtained with a thermal recovery in kJ of 96.1, 92.7 and 88.8 per cent for HMC, Baum jig and WOC with corresponding dp of 1.87, 1.85 and 1.86 respectively.

WASHING TESTS

The processing of the Wapiti coal sample at the Fuel Processing Laboratory pilot plant facilities included feed preparation, two cleaning circuits, dewatering and water treatment. A detailed description of the 10

tonne/hr. pilot plant facility has been reported earlier (3) and a simplified flowsheet is shown in Figure 8. The following is a brief outline of the pilot plant circuits.

Feed Preparation: The raw coal is prepared to a 12.7 mm top size by screening out the minus 10 mm coal and recombining it with the plus 10 mm fraction which has been crushed in a hammer mill.

Cleaning: a) Coarse coal circuit: The bulk raw coal slurry 12.7 mm x 0 has the minus 0.5 mm fraction removed before processing in a Batac jig. The Batac jig produces a reject product, a middlings which is recirculated and a coarse clean coal product.

b) Fine coal circuit: The minus 0.5 mm fraction which was removed before coarse coal cleaning is processed in a two stage 200 mm diameter water-only cyclone.

Dewatering: The coarse and fine clean coal fractions are combined and dewatered together in a pusher-type centrifuge. The thickener underflow or fine reject is dewatered in a solid bowl centrifuge while the coarse reject is dewatered over a 0.6 mm vibrating screen.

Water treatment: Process water containing classifier cyclone overflow and secondary compound water cyclone underflow is treated in a bottom fed thickener to produce clarified water for recirculation. The thickened fine reject is then dewatered in a solid bowl centrifuge.

TEST PROCEDURE

The objective of the pilot plant washing tests was to evaluate the performance of the Batac jig in cleaning smalls (12.7 x 0.6 mm) coal, to determine size degradation during washing and to produce clean coal with approximately 18% ash or above 23730 kJ/kg-(db). Optimum thermal recovery was the main criterion in setting the separation cutpoints of both the smalls and fines (minus 0.6 mm) cleaning circuits. A total of five tests were run with some changes in dp settings. Froth flotation was not included in the

fines circuit due to poor results from bench scale tests. A new cutpoint adjustment system for the Batac jig was tested and compared to original floats (control) by comparing the set dp and actual dp from distribution curves.

After the initial adjustment of the Batac jig and cyclones settings, a short preliminary run was made and samples collected for analysis to determine if further adjustment of the equipment was required. Incremental samples were taken of the raw coal, clean coal and reject products for all tests. The end products of the long runs and some of the intermediate products were collected to evaluate the overall performance of the plant and determine material balance.

The ash and moisture contents of products were determined following each test run. Screen and float-sink on the samples of the main runs were carried out by the Birtley Engineering Laboratory in Calgary along with attrition tests.

DISCUSSION OF RESULTS

A total of 11.78 tonne of raw coal with 28.28% ash was washed in the pilot plant, producing a clean coal yield of 69.87% with 19.60% ash (Table 8). Average thermal recovery was 80.39%, however, Test 3 with a relatively high cutpoint indicated 85.6% thermal recovery. Results indicate that cutpoints lower than 1.7 would result in a decrease in the thermal recovery. Density separation usually is not effective for particle sizes below 0.15 mm. As a result, all minus 0.15 mm reported with the fine reject (Figure 8) and caused relatively lower thermal recovery than might be expected (Table 9).

PLANT PERFORMANCE

Plant performance is defined by the probable error (r) which reflects the sharpness of separation at a given cutpoint (dp). These parameters are derived from the distribution curve. The distribution curve is a plot of the percentage of the feed to a washing unit that reports as refuse versus the relative density. The cutpoint (dp) is defined as the relative density at which 50% of the feed reports to refuse and 50% to

product. The probable error (r) for a distribution curve is one half of the difference of the relative density interval at the ordinates of 25 and 75 per cent and this is a measure of the slope of the middle portion of the distribution curve. The better the separation, the steeper the slope of this curve and the smaller the probable error.

Batac Jig Performance

Table 10 shows the summary of four Batac jig tests performance for dp between 1.65 and 1.80. Error curves related to the two size ranges of 12.7 x 2 mm and 2 x 0.6 mm fractions are shown in Figure 9 and combined in Figure 10. As can be expected dp and r increased with decrease in size from 1.71 and 0.10 (dp, r) for the 12.7 x 2 mm fraction to 2.15 and 0.22 for the 2 x 0.6 mm fraction respectively. The average r from four tests is 0.14 corresponding to 1.73 average dp (Table 10). Fluctuation in the water feed rate to the Batac jig during testing might have caused deterioration in the separation efficiency for Test 3 and 4. The Batac jig results from Test 2 to 5 are compared with predicted performance from a Baum jig model (Figure 11). Test 5 data are excluded due to segregation of coarse high ash particles in the raw coal bin that made the size and washability of Test 5 feed different from previous tests. Batac jig performance compared favourably and generally produced better results than the Baum jig predicted data. By extrapolating pilot plant results, the projected thermal recovery at 21.4% ash in clean coal is 96.3% at approximately 1.86 dp (figure 11). Lower ash levels than 21.4% can also be predicted by extrapolation or interpolation from pilot plant results.

The new system for setting the Batac jig dp is tested and compared with the dp determined from error curves. The new system includes a ring of a relative density equal to the dp that would float between the reject and clean coal beds and a change in height below or above the set height would trigger the opening or closing the reject gate. Table 10 data indicate that ring relative density is comparable to the measured relative density of separation for the 12.7 x 2 mm. However, for the 2 x 0.6 mm fraction, the actural dp's are much higher than the rings relative densities. This is possible caused by relatively high upward flow of water which influence fine particles more than coarse ones.

Water-Only Washing Cyclone Performance

The two stage water-only cyclones (WOC) are set to separate at high dp to mostly scalp particles heavier than 2.0 relative density. The two stage cyclones produced acceptable reject in all tests with 50 to 55% ash (r = 0.31 at 2.09 dp). However, most of the 0.15 mm x 0 fraction was removed in the classifier cyclone and reported to the fine reject. This resulted in thickener tailings with 30-35% ash (Fig. 8), indicating loss of fine coal to the reject and in turn reduction in the overall clean coal recovery.

SIZE DEGRADATION

Changes in screening characteristics resulting from degradation during washing can be evaluated by comparing the analyses of raw coal and reconstituted feed. The reconstituted feed is obtained by combining the individual product size analyses, weighted according to their respective mass yields.

The screen analysis of reconstituted feed as compared with the raw feed analysis (Table 3), and wet attrition test for 7 min. (Figure 12) indicates slight change in size consist. Degradation during pilot plant washing increased the amount of minus 0.6 mm from 29% to 31% (for 12.7 mm x 0). The wet attrition test (12.7 mm x 0) shows 34% by mass of minus 0.6 mm indicating more degradation than by washing.

The predicted amount of minus 0.6 mm in the run-of-mine (ROM) from ΔP index measurement is 20.7% by mass, as calculated from the following equation (4):

$$\text{Mass\% of minus 0.6 mm in ROM} = 14.90 + 0.68\ \Delta P$$

It is worth noting that the amount predicted for ROM based on ΔP value of 8.5 compares favourably with the amounts of minus 0.6 measured from wet attrition test for 7 min. (19.5% by mass of minus 0.6 mm).

PROPOSED FLOWSHEET

Screen analysis (Table 2) indicate that the minus 6 mm fraction with 21.3% ash (23767 kJ/kg) can be blended with washed plus 6 mm to produce a blend with approximately 23730 kJ/kg (10200 BTU/lb). Dry screening of fine coal before washing would simplify the washing plant flowsheet and reduce

both capital and operating costs.

The schematic flowsheet in Figure 13 is suggested and expected to produce clean coal at 21.4% ash equivalent to 23730 kJ/kg. The flowsheet includes one step cleaning for the plus 10 mm size fraction in a density separator. A simple fine treatment circuit is added to dewater the misplaced minus 10 mm or degraded coarse particles.

Performance prediction for heavy medium bath (HMB) and jig for the plus 6 mm fraction is shown in Figure 14. Due to the relatively high near density material between 1.6 and 1.8 dp, the HMB indicates 90% heat recovery as compared to 83.5% for the jig. As a result the HMB is suggested as better suited to Wapiti coal for optimum heat recovery. In case the fines are higher in ash than what is indicated above, the HMB is capable to produce low ash coal at dp less than 1.7, to allow the blend of coarse clean coal and unwashed fines to meet the target of 23730 kJ/kg or higher if necessary. Based on the schematic flowsheet (Figure 13) and Figure 14, the overall heat recovery is expected to be approximately 95%.

CONCLUSIONS AND RECOMMENDATIONS

1) Washability data indicate no washing is required for the minus 6 mm to achieve 23730 kJ/kg in the final product. The fine coal indicates lower ash values than the coarse fractions (plus 6 mm). Crushing the raw coal to minus 12.7 mm increased the ash of the fines which indicates the presence of soft high ash particles. No significant improvement in coal washability is indicated by crushing the raw coal from 50 mm to 12.7 mm top size. It is beneficial to wash the coal as coarse as possible and remove the fines fraction (minus 2 mm to 10 mm) before washing.

2) Both pilot plant testing and wet attrition tests indicate limited degradation. The amount of minus 0.6 mm predicted for future run-of-mine raw coal is 20.7% by mass. The amount of minus 0.6 mm measured by wet attrition is 19.5% by mass.

3) Batac jig testing for the 12.7 x 0.6 mm shows better performance than can be expected from a Baum jig model. The Batac jig performed well for the

12.7 mm fractions, however high dp and probable error are indicated for the 2 x 0.6 mm fraction. Projection from washing in the Batac jig of 12.7 x 0.6 mm shows a thermal recovery of 96.3% to produce clean coal with 21.4% ash (db) at 1.86 dp. Pilot plant results indicate that washing of the fines (minus 0.6 mm) would result in the loss of most of the minus 0.15 mm to the reject causing lower overall thermal recovery.

4) Based on coal characteristics and pilot plant testing an outline of a flowsheet is proposed. The flowsheet includes one step cleaning for the plus 10 mm fraction in a heavy medium bath instead of a Batac jig due to high percentage of near density material between 1.6 and 1.8 dp. The minus 10 mm is dry screened before washing and combined with coarse clean coal. The overall thermal recovery is estimated to be about 95% to produce coal with 23730 kJ/kg.

REFERENCES

1. Mikhail, M.W. "The Batac Jig: description, application and possible installation in the pilot plant of the Western Research Laboratory"; Divisional Report ERP/ERL 80-49 (INT); CANMET, Energy, Mines and Resources Canada; 1980.

2. LePage, A.J. and Pollard. F. "Methods for providing reliable data for coal preparation plant design"; International Coal Preparation Congress; Sydney; Australia; p. D2; May 1976.

3. Mikula, R.J., Mikhail, M.W., Salama, A.I.A. and Humeniuk, O.E. "Some EMR facilities in Western Canada for R&D on beneficiation of Canadian coals"; Proceedings of the 2nd CIM Technical Conference on Western Canadian Coals; Edmonton; June 1982.

4. Mikhail, M.W., and Patching, T.H. "Methods for predicting size degradation of Western Canadian coals"; Fuel; V. 60; p 1073; Nov. 1981.

Table 1 - Analysis of Gulf - Wapiti - Adit #1 bulk shipment

	As Rec'd	Dry (db)
Moisture	11.3	-
Ash (%)	25.1	28.3
Volatile Matter (%)	25.5	28.8
Fixed Carbon (%)	38.1	42.9
kJ/kg (det.)	18922	21334
Sulphur (%)	0.43	0.49
Sulphur (kg/MkJ)	0.23	
Hardgrove Grindability Index	49	

Table 2 - Size ash and heat value analyses of Wapiti raw coal (50 mm x 0)

Particle Size mm		Mass %	Ash %	kJ/kg*	Cumulative Mass %	Cumulative Ash %	Cumulative kJ/kg
	+ 25	12.29	41.37	17316	12.29	41.37	17316
25	- 12.7	16.56	37.14	18015	28.85	38.94	17717
12.7	- 6.3	19.63	31.14	19717	48.48	35.78	18527
6.3	- 3.35	10.86	27.67	20848	59.34	34.30	18952
3.35	- 2.0	14.80	20.83	22711	74.14	31.61	19702
2.0	- 0.6	15.19	17.73	23529	89.33	29.25	20353
0.6	- 0.15	7.21	19.15	22624	96.74	28.50	20523
0.15	- 0.074	1.38	19.41	22423	97.92	28.37	20549
0.074	- 0.044	0.89	18.46	22373	98.81	28.28	20566
	- 0.044	1.19	33.30	17879	100.00	28.34	20534
TOTAL		100.00	28.34	20534	-	-	-

*All kJ/kg values are calculated based on kJ - Ash relationship

Table 3 - Size, ash and heat value analyses of crushed raw coal fed to the pilot plant (12.7 mm x 0)

Particle Size mm		Mass %	Ash %	kJ/kg	Cumulative Mass %	Cumulative Ash %	Cumulative kJ/kg
+ 12.7		0.21	53.46	12039	0.21	53.46	12039
12.7	- 6.3	3.00	48.21	14263	3.21	48.55	14118
6.3	- 3.35	19.51	34.70	18610	22.72	36.66	17975
3.35	- 2.0	28.69	27.43	20958	51.41	31.51	19640
2.0	- 0.6	29.60	22.63	22208	81.01	28.26	20578
0.6	- 0.15	13.89	23.55	21577	94.90	27.57	20724
0.15	- 0.074	2.45	25.49	21094	97.35	27.52	20734
0.074	- 0.044	1.12	24.14	21428	98.47	27.48	20742
	- 0.044	1.53	36.25	17629	100.00	27.62	20694
TOTAL		100.00	27.62	20694	-	-	-

Table 4 - Washing characteristics of Wapiti coal 50 x 0.6 mm (89.33% of total)

Relative Density	Elementary data			Cumulative data					
				Float			Sink		
	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg
Float - 1.30	4.75	3.94	30148	4.75	3.94	30148	100.00	28.65	21063
1.30 - 1.35	7.17	6.56	29185	11.92	5.52	29569	95.25	29.88	20610
1.35 - 1.40	14.07	9.42	28133	25.99	7.63	28791	88.08	31.78	19912
1.40 - 1.45	14.01	13.56	26611	40.00	9.71	28028	74.01	36.03	18349
1.45 - 1.50	10.65	18.30	24858	50.65	11.51	27363	60.00	41.28	16419
1.50 - 1.60	12.76	26.54	21838	63.41	14.54	26252	49.35	46.24	14596
1.60 - 1.80	17.18	41.17	16459	80.59	20.21	24164	36.59	53.11	12070
1.80 - 2.00	11.64	58.19	10201	92.23	25.01	22402	19.41	63.67	8186
2.00 - 2.17	4.95	67.74	6689	97.18	27.18	21601	7.77	71.88	5168
2.17 - Sink	2.82	79.14	2497	100.00	28.65	21063	2.82	79.14	2497

Table 5 - Washing characteristics of Wapiti coal 0.6 x 0.15 mm (7.21% of total).

Relative Density	Elementary data			Cumulative data					
				Float			Sink		
	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg
Float - 1.30	2.01	2.99	30498	2.01	2.99	30498	100.00	18.38	24879
1.30 - 1.35	10.88	3.91	30159	12.89	3.77	30212	97.99	18.69	24764
1.35 - 1.40	12.30	6.42	29236	25.19	5.06	29735	87.11	20.54	24090
1.40 - 1.45	23.26	8.13	28608	48.45	6.53	29194	74.81	22.86	23244
1.45 - 1.50	19.02	11.55	27350	67.47	7.95	28674	51.55	29.51	20823
1.50 - 1.60	10.94	19.48	24434	78.41	9.56	28083	32.53	40.01	17007
1.60 - 1.80	10.51	33.23	19378	88.92	12.36	27054	21.59	50.41	13243
1.80 - 2.00	4.84	48.72	13683	93.76	14.23	26364	11.08	66.72	7424
2.00 - 2.17	1.83	62.10	8763	95.59	15.15	26027	6.24	80.67	2570
2.17 - Sink	4.41	88.38	~ 0	100.00	18.38	24879	4.41	88.38	~ 0

Table 6 - Washing characteristics of Wapiti coal fed to pilot plant 12.7 x 0.6 mm (81.01% of total)

Relative Density	Elementary data			Cumulative data					
				Float			Sink		
	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg
Float - 1.30	1.14	2.71	30601	1.14	2.71	30601	100.00	27.57	21458
1.30 - 1.35	9.51	5.01	29755	10.65	4.76	29846	98.86	27.86	21353
1.35 - 1.40	16.06	8.42	28501	26.71	6.96	29037	89.35	30.29	20458
1.40 - 1.45	13.78	12.06	27163	40.49	8.70	28399	73.29	35.09	18696
1.45 - 1.50	9.32	17.39	25203	49.81	10.32	27801	59.51	40.42	16735
1.50 - 1.60	13.46	25.27	22305	63.27	13.50	26632	50.19	44.69	15163
1.60 - 1.80	18.35	40.14	16838	81.62	19.49	24430	36.73	51.81	12546
1.80 - 2.00	10.59	57.29	10531	92.21	23.83	22834	18.38	63.46	8261
2.00 - 2.17	4.94	67.34	6836	97.15	26.05	22020	7.79	71.86	5175
2.17 - Sink	2.85	79.69	2295	100.00	27.57	21458	2.85	79.69	2295

Table 7 - Washing characteristics of Wapiti coal fed to pilot plant 0.6 x 0.15 mm (13.89% of total)

Relative Density	Elementary data			Cumulative data					
				Float			Sink		
	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg
Float - 1.30	0.80	3.61	30270	0.80	3.61	30270	100.00	23.50	22955
1.30 - 1.35	11.68	4.22	30045	12.48	4.18	30059	99.20	23.66	22896
1.35 - 1.40	11.50	7.25	28931	23.98	5.65	29518	87.52	26.26	21942
1.40 - 1.45	17.15	9.00	28288	41.13	7.05	29005	76.02	29.13	20884
1.45 - 1.50	14.65	12.25	27093	55.78	8.41	28503	58.87	35.00	18728
1.50 - 1.60	12.39	19.56	24405	68.17	10.44	27758	44.22	42.54	15956
1.60 - 1.80	13.42	33.33	19342	81.59	14.21	26374	31.83	51.48	12667
1.80 - 2.00	7.39	50.51	13024	88.98	17.22	25265	18.41	64.71	7802
2.00 - 2.17	3.25	63.57	8222	92.23	18.85	24665	11.02	74.24	4300
2.17 - Sink	7.77	78.70	2659	100.00	23.50	22955	7.77	78.70	2659

Table 8 - Summary of products analyses - washing tests (ash contents on dry basis)

Test No.	%	Raw Coal	Clean Coal		Final Products		
			Batac jig	Water-Only Cyclone	Clean Coal	Coarse Reject	Fine Reject
1	Ash	26.51	16.74	17.56	17.63	55.98	46.01
	Moisture*	8.95	-	-	14.07	28.08	13.49
	Yield	100.00	-	-	71.77	20.96	7.27
2	Ash	27.58	19.56	18.92	20.38	58.30	45.21
	Moisture	7.73	-	-	12.48	24.11	16.34
	Yield	100.00	-	-	76.58	18.52	4.90
3	Ash	27.49	20.16	18.57	20.50	56.36	41.41
	Moisture	-	-	-	11.06	22.13	17.38
	Yield	100.00	-	-	76.48	18.15	5.37
4	Ash	29.02	18.68	19.43	19.28	52.34	37.82
	Moisture	8.80	-	-	13.52	19.12	21.17
	Yield	100.00	-	-	64.03	30.49	5.48
5	Ash	31.42	17.59	15.43	17.59	47.93	33.56
	Moisture	-	-	-	10.39	21.51	20.76
	Yield	100.00	-	-	50.45	45.42	4.13

* Total moisture

Table 9 - Thermal recovery in relation to cutpoint

Test	Raw Coal		Clean Coal			
	Mass kg	Ash %	Yield %	Ash %	dp (Batac Jig)	Thermal Recovery %
1	907.2	26.51	71.77	17.63	1.70	82.49
2	1814.4	27.58	76.58	20.38	1.72	86.02
3	4535.9	27.49	76.48	20.50	1.80	85.62
4	3234.6	29.02	64.03	19.28	1.70	74.98
5	1285.5	31.42	50.45	17.59	1.65	63.24
TOTAL	11777.6	28.28	69.87	19.60	-	80.39

Table 10 - Summary of Batac jig performance

Test	Jig Set dp	Actual dp			Performance					
		12.7 x 2 mm	2 x 0.6 mm	12.7 x 0.6 mm	12.7 x 2 mm		2 x 0.6 mm		12.7 x 0.6 mm	
					r*	ea**	r	ea	r	ea
2	1.70	1.71	2.15	1.76	0.10	62	0.22	92	0.11	69
3	1.70	1.72	2.14	1.80	0.14	86	0.21	100	0.16	104
4	1.64	1.62	1.97	1.70	0.11	78	0.22	111	0.17	102
5	1.66	1.63	1.82	1.65	0.12	74	0.17	108	0.12	83
Average	1.675	1.670	2.02	1.727	0.12	75	0.20	103	0.14	89

* Probable error
** Error area

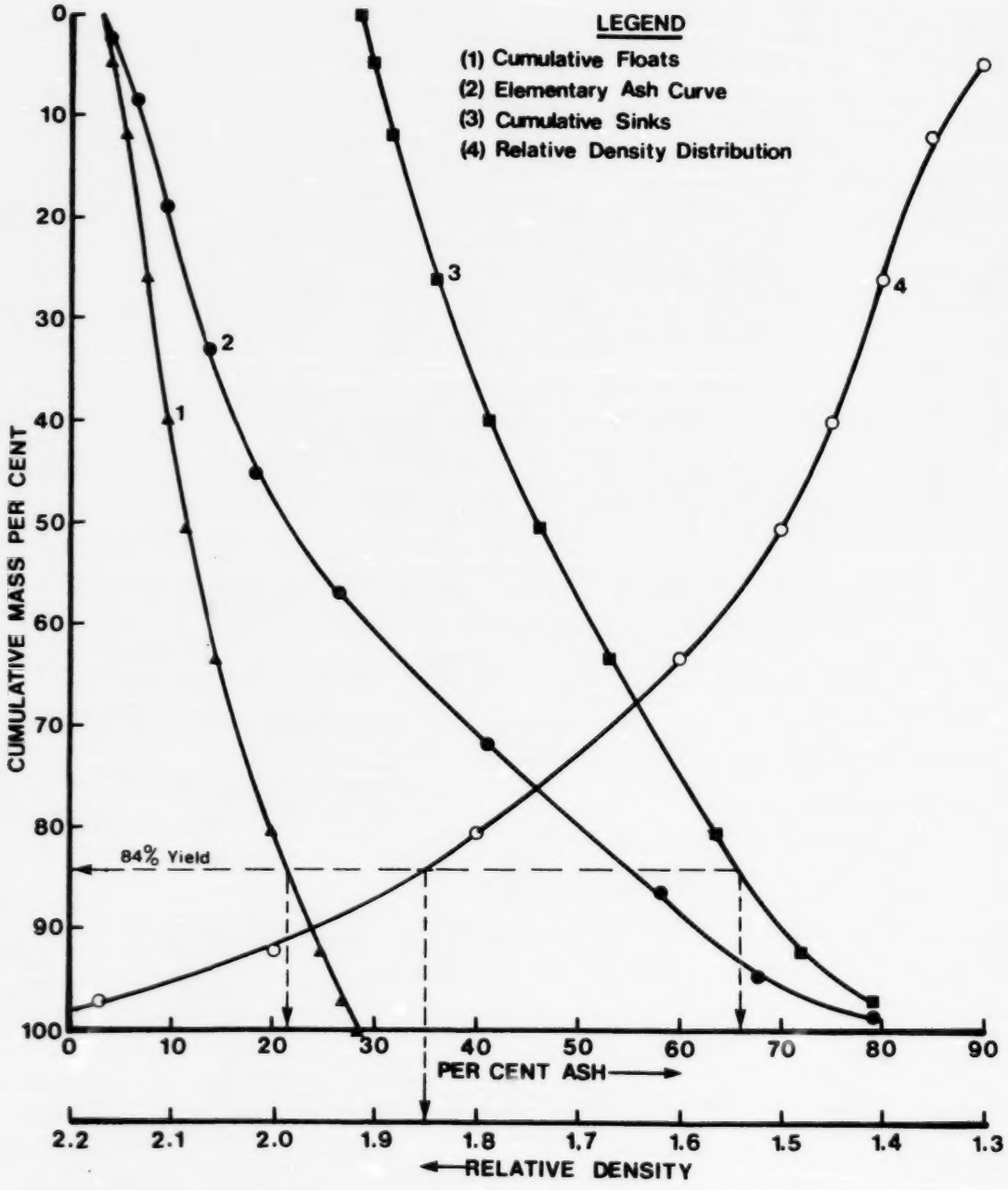

Fig. 1 - Washability curves: Wapiti coal 50 x 0.6 mm (89.33% of total)

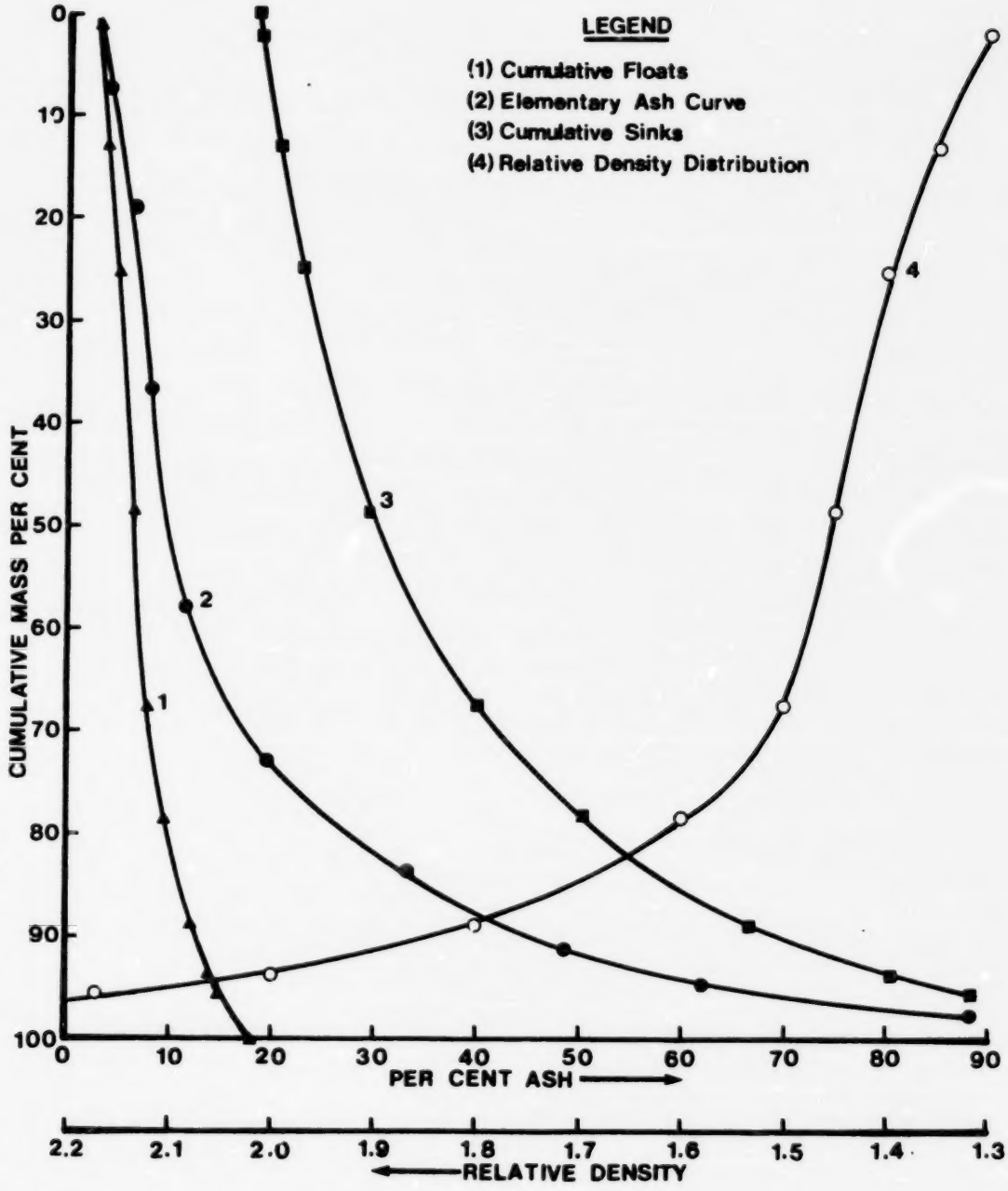

Fig. 2 - Washability curves: Wapiti coal 0.6 x 0.15 mm (7.2% of total)

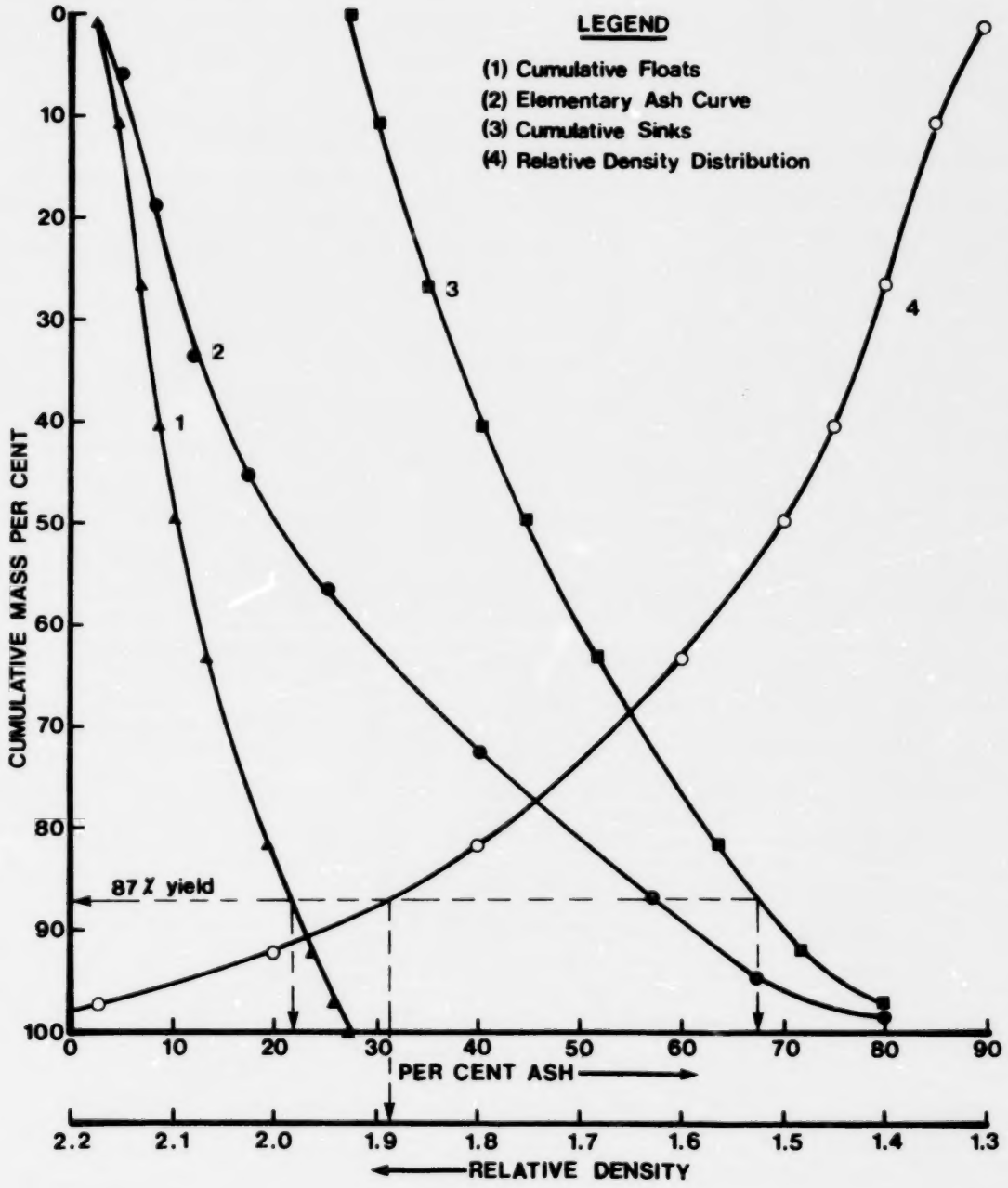

Fig. 3 - Washability curves: Wapiti coal (feed to pilot plant)
12 x 0.6 mm (81.01% of total)

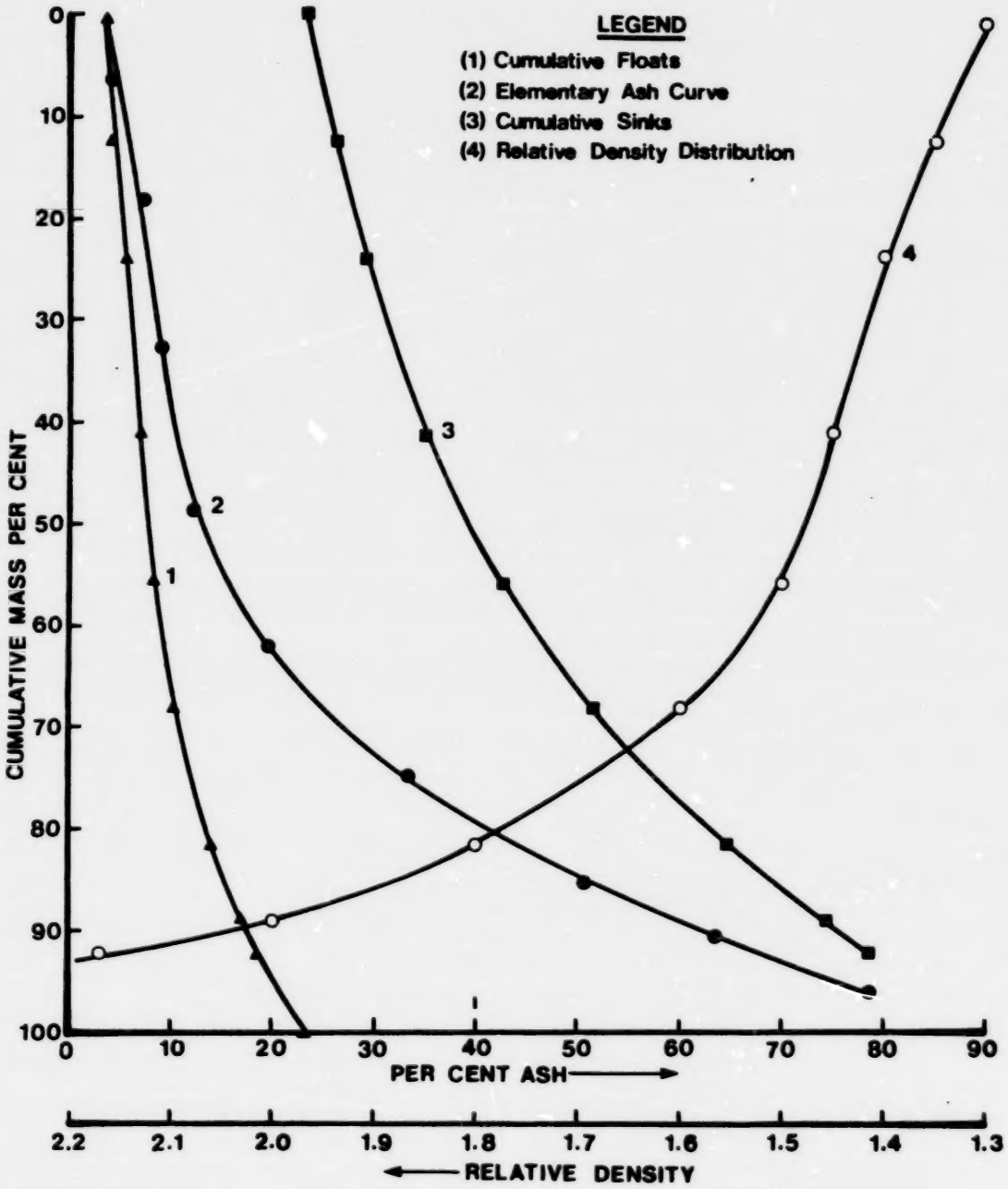

Fig. 4 - Washability curves: Wapiti coal (feed to pilot plant) 0.6 x 0.15 mm (13.89% of total)

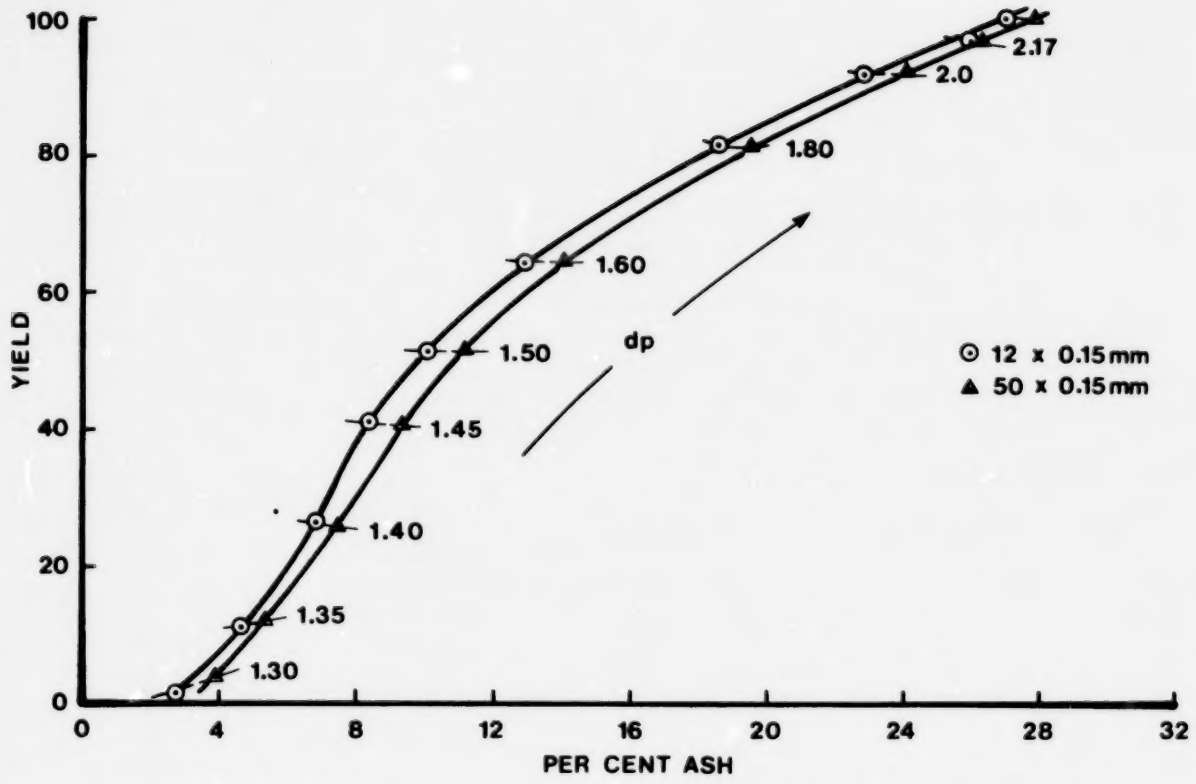

Fig. 5 - Effect of crushing on coal washability

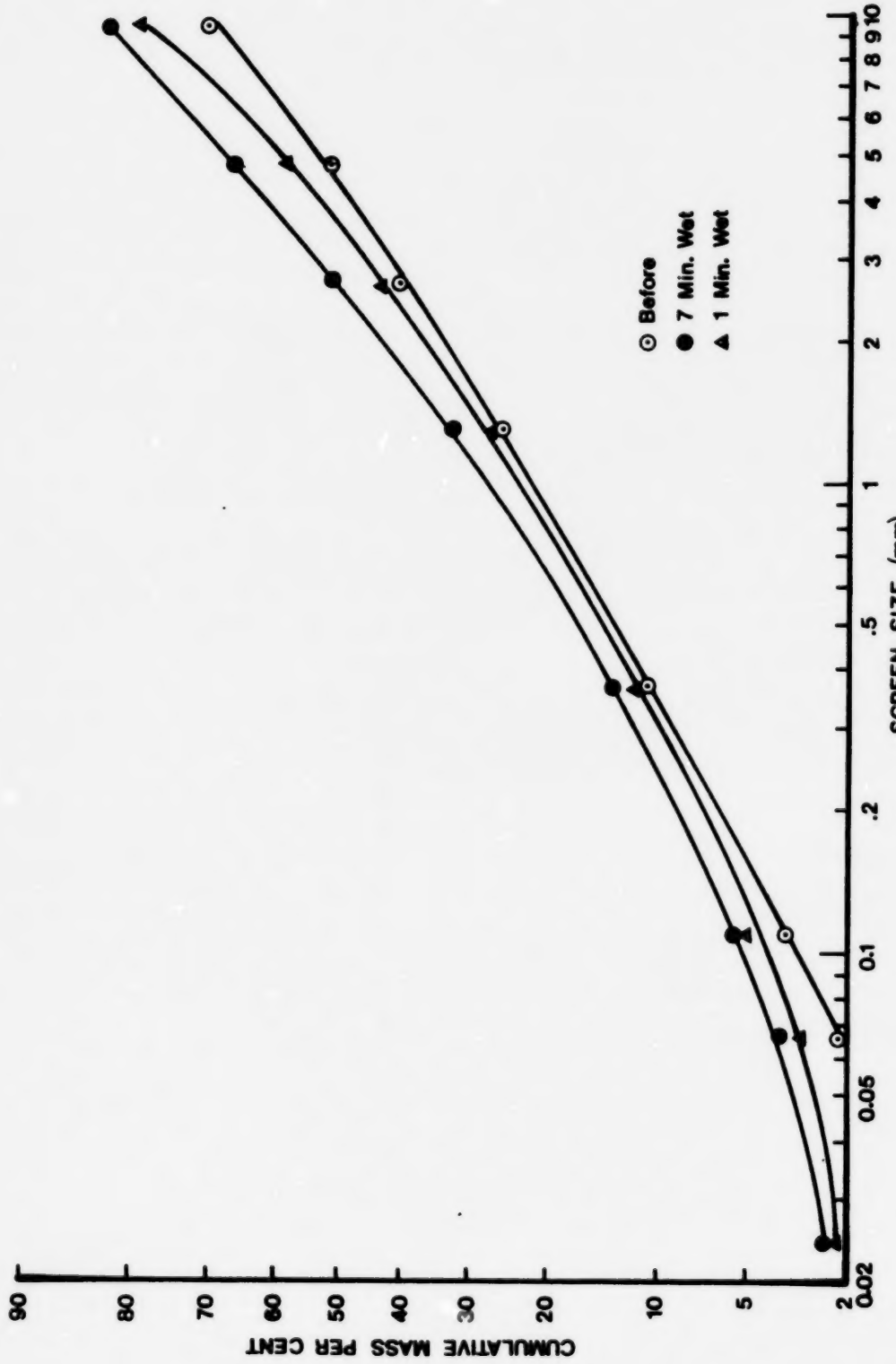

Fig. 6 - Size degradation during wet attrition tests (50 mm x 0)

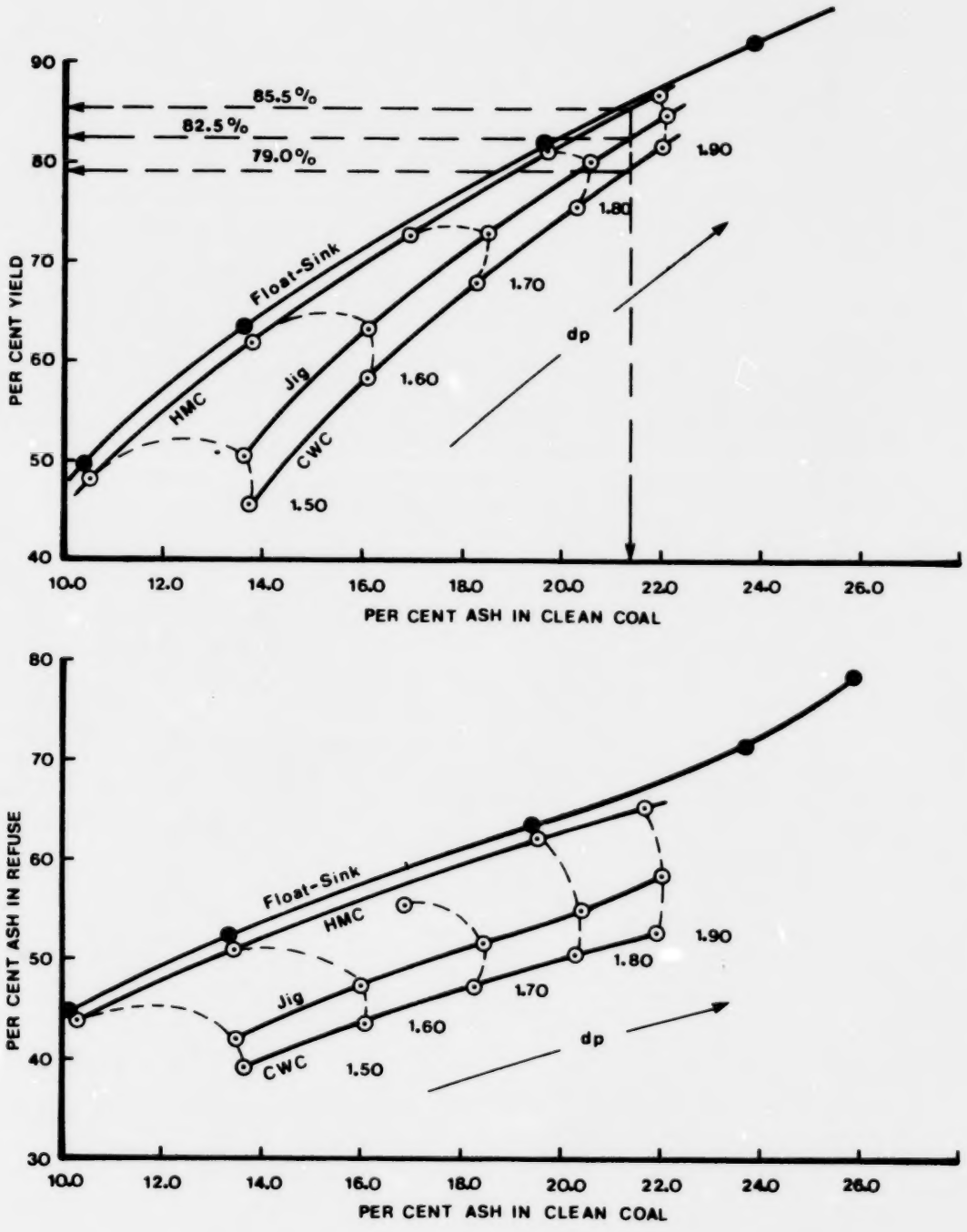

Fig. 7 - Performance evaluation prediction (12 x 0.6 mm)

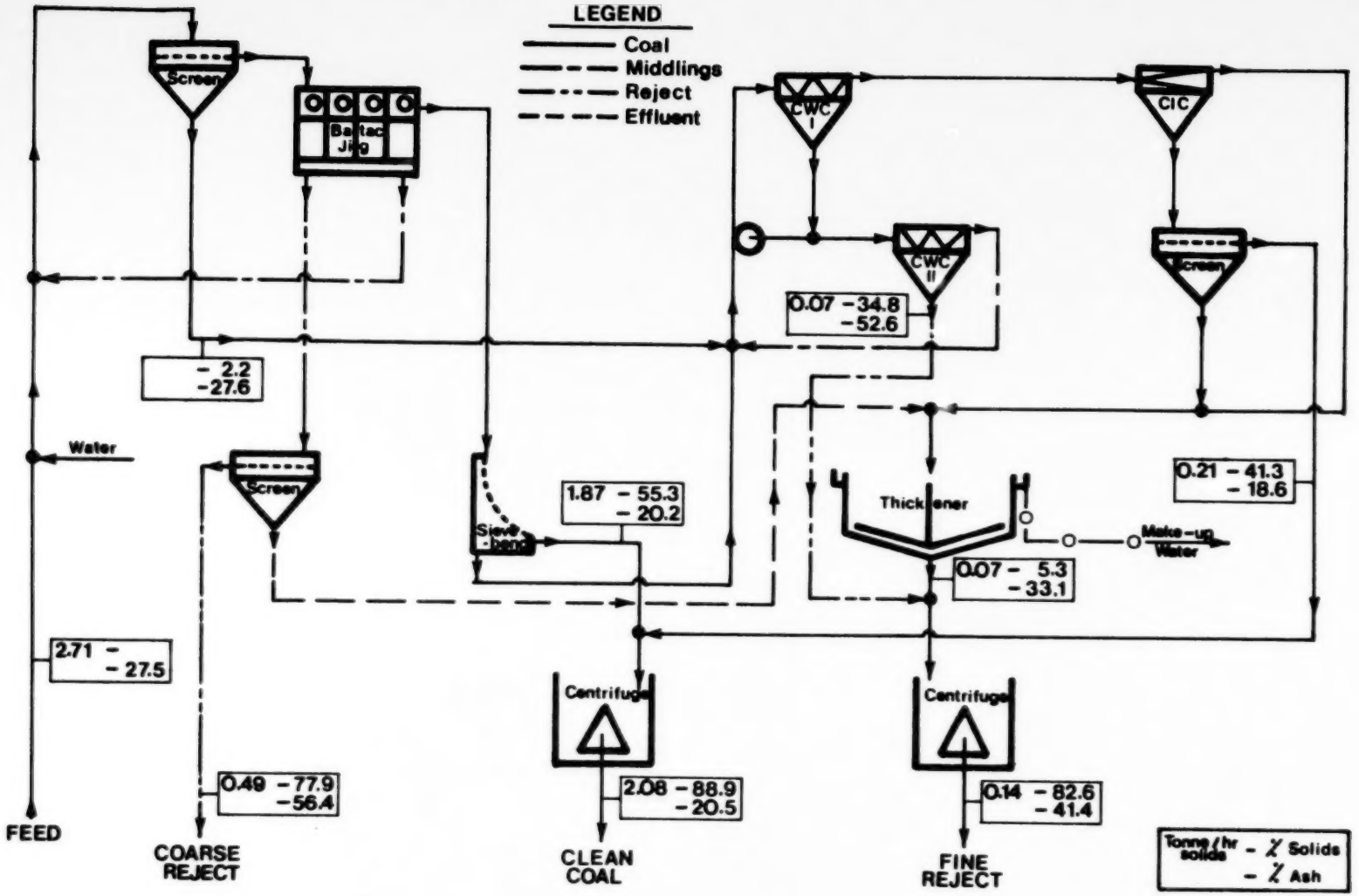

Fig. 8 - Simplified pilot plant flowsheet with partial material balance

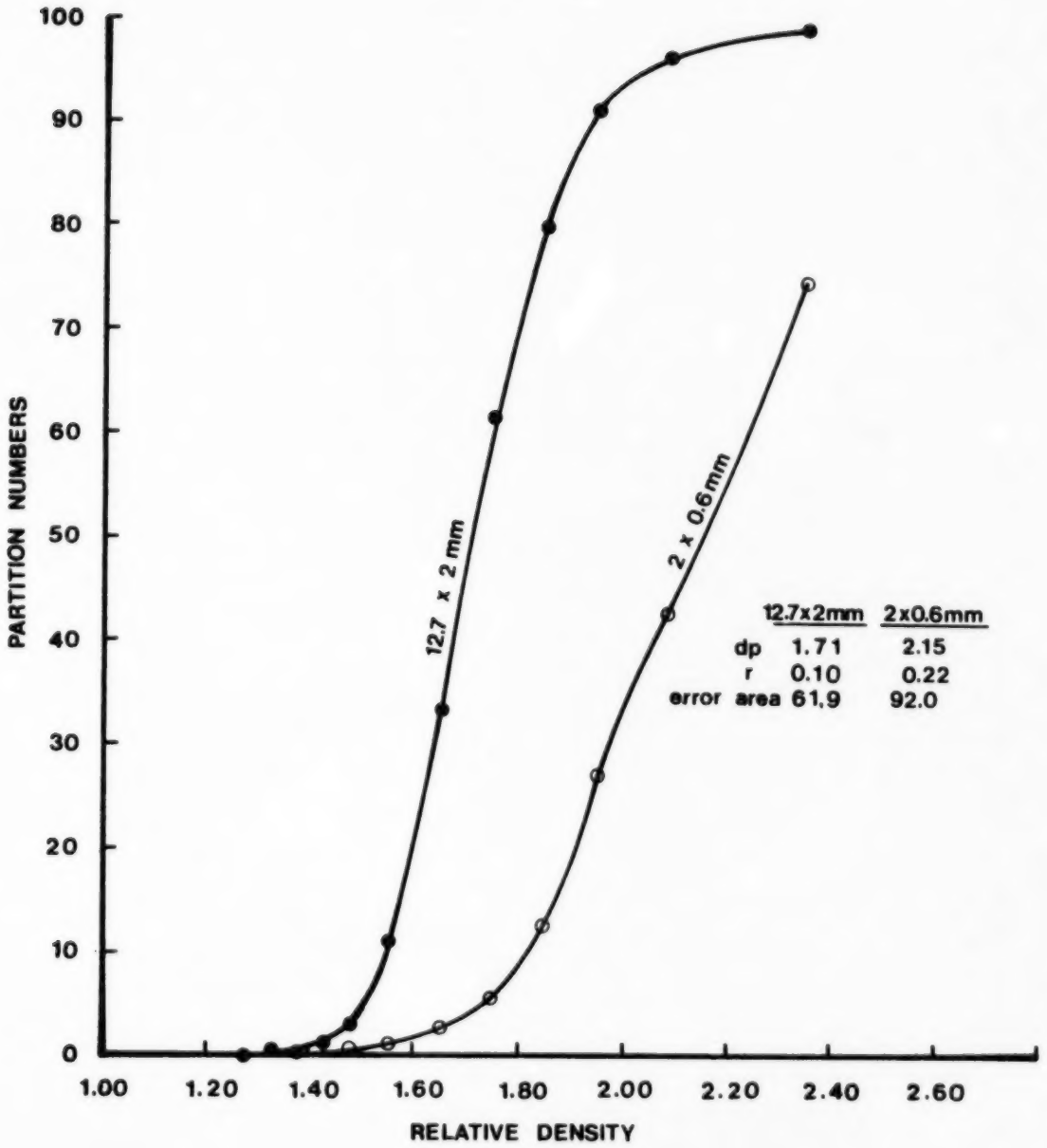

Fig. 9 - Error curves for Batac jig

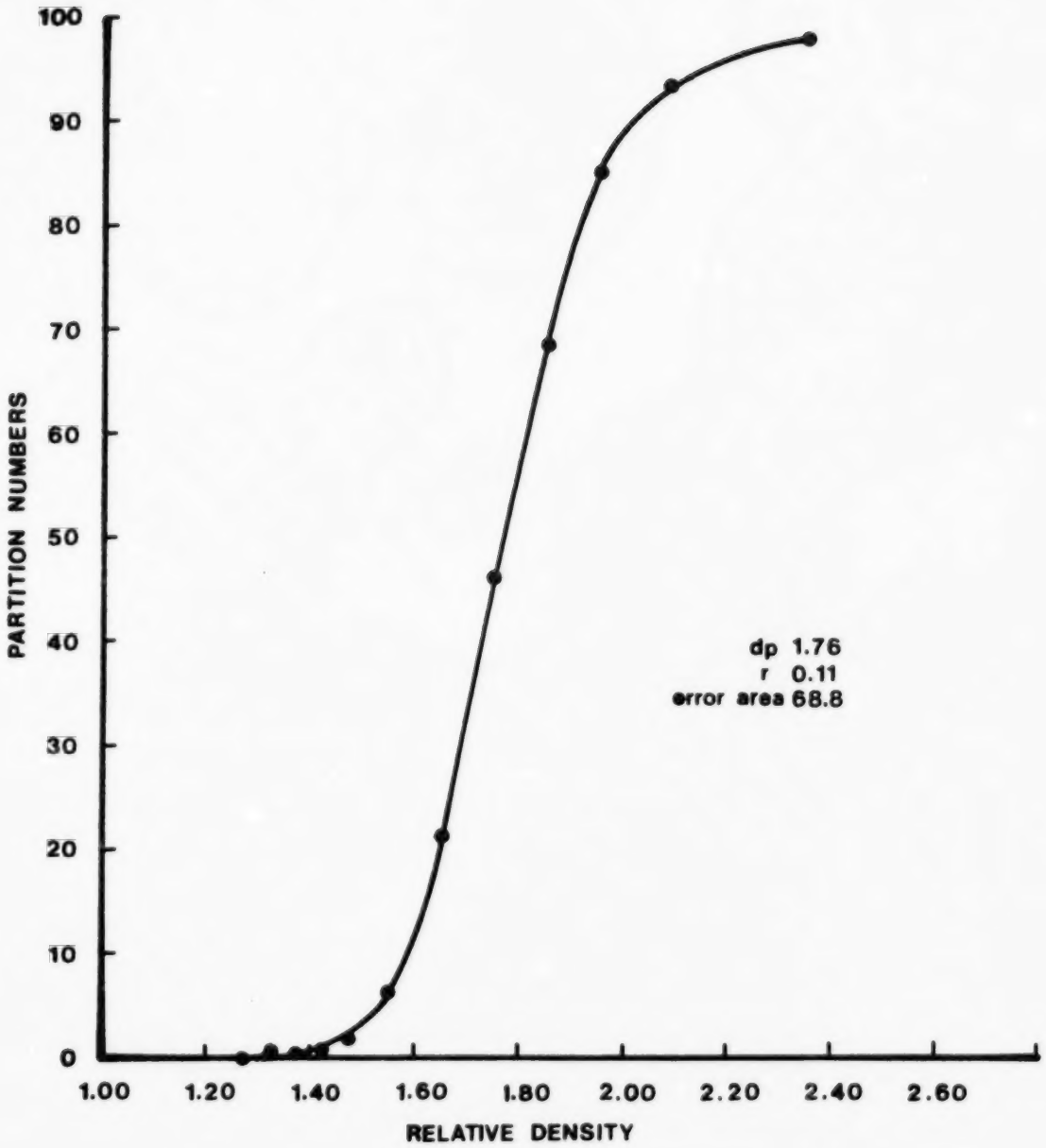

Fig. 10 - Error curve for Batac jig 12 x 0.6 mm

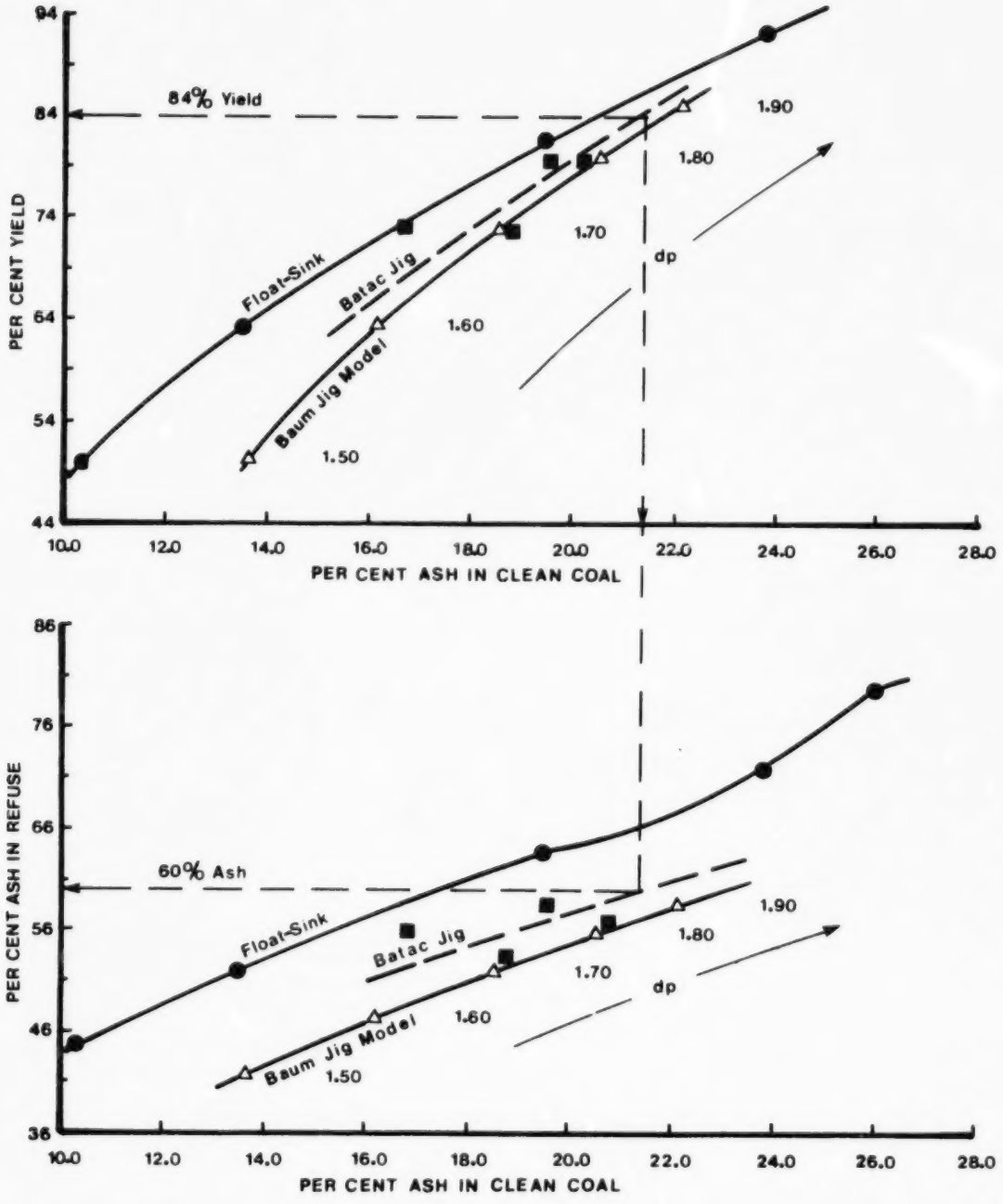

Fig. 11 - Comparison between Baum jig predicted data and Batac jig pilot plant results (12 x 0.6 mm)

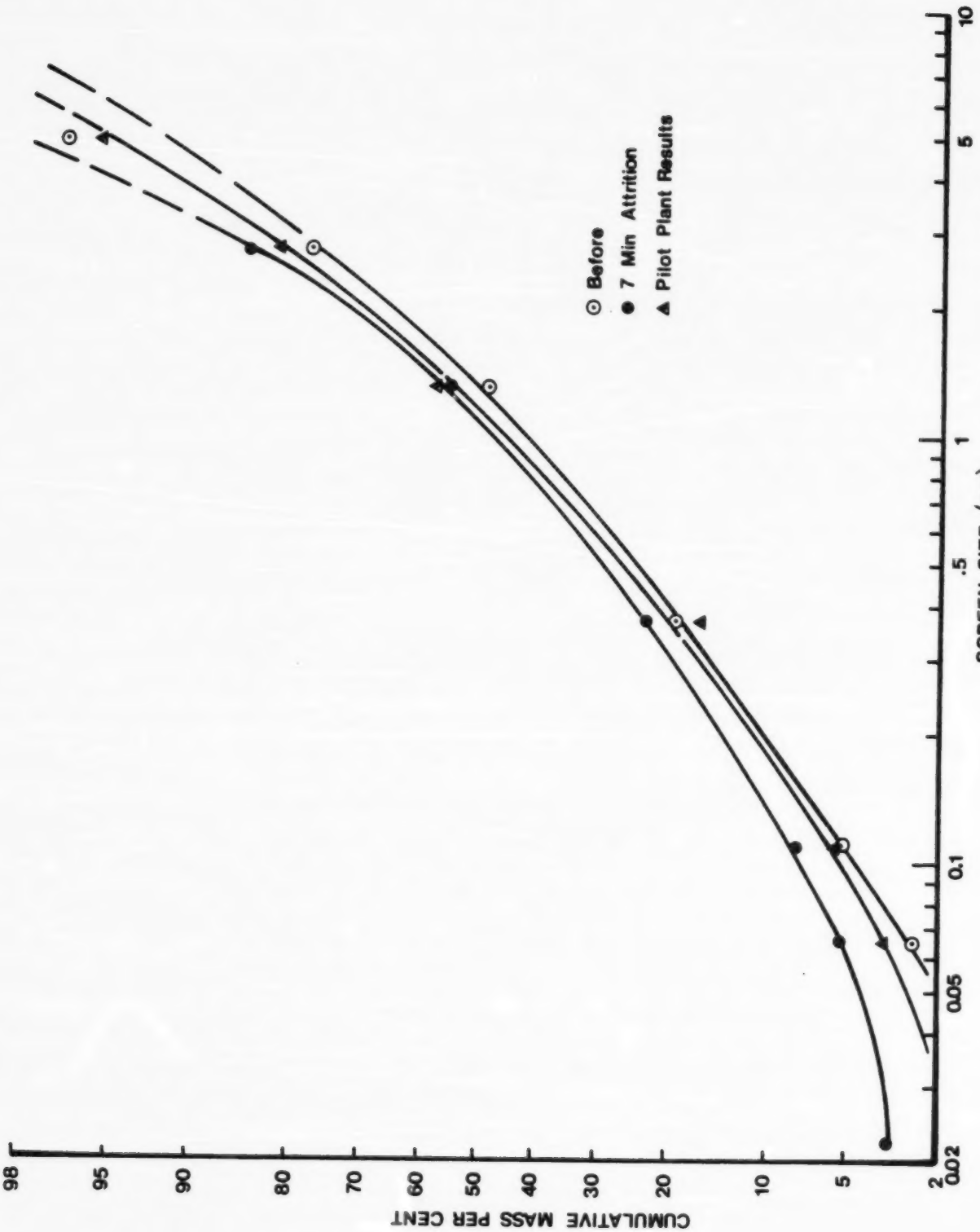

Fig. 12 - Comparison between size degradation by attrition and washing tests (12 mm x 0)

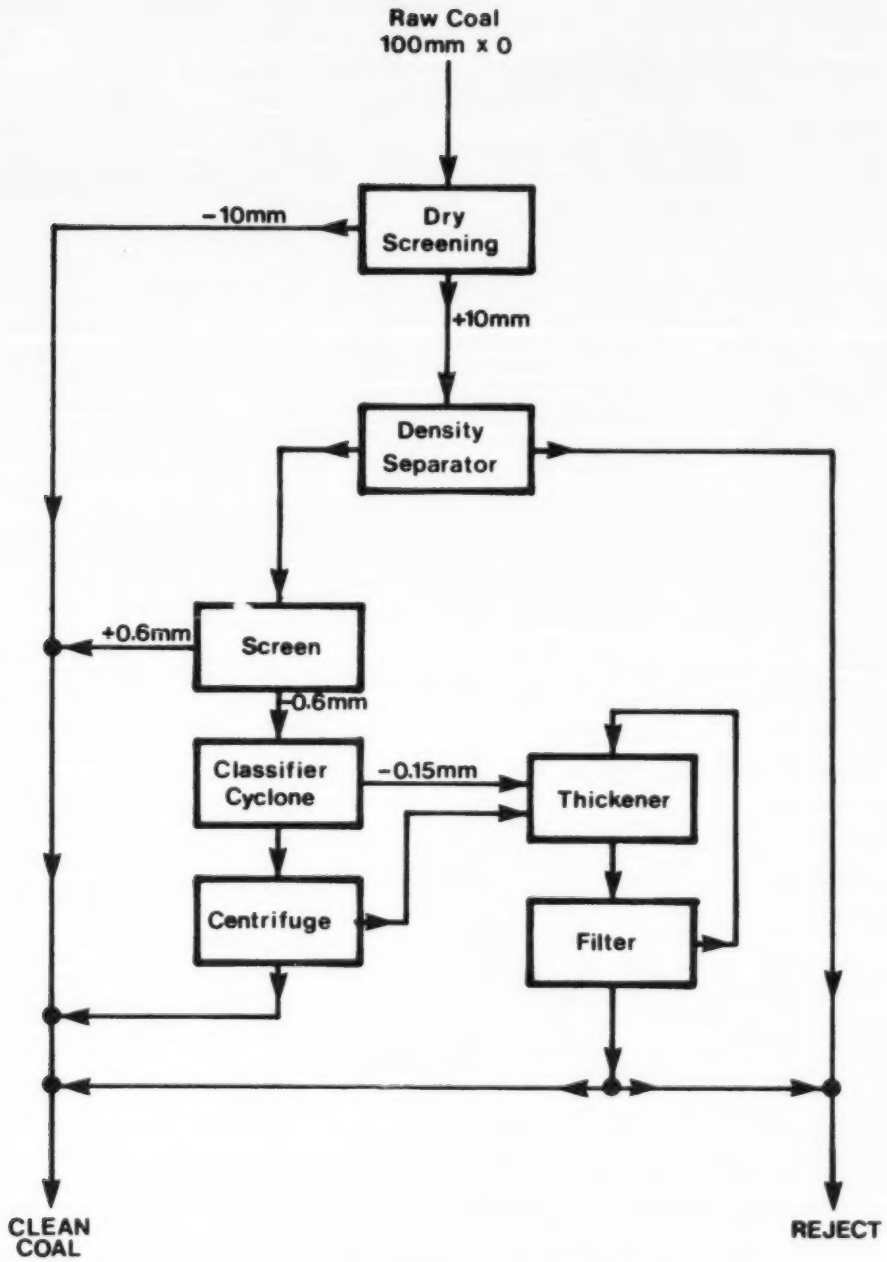

Fig. 13 - Schematic of proposed preparation plant - Wapiti

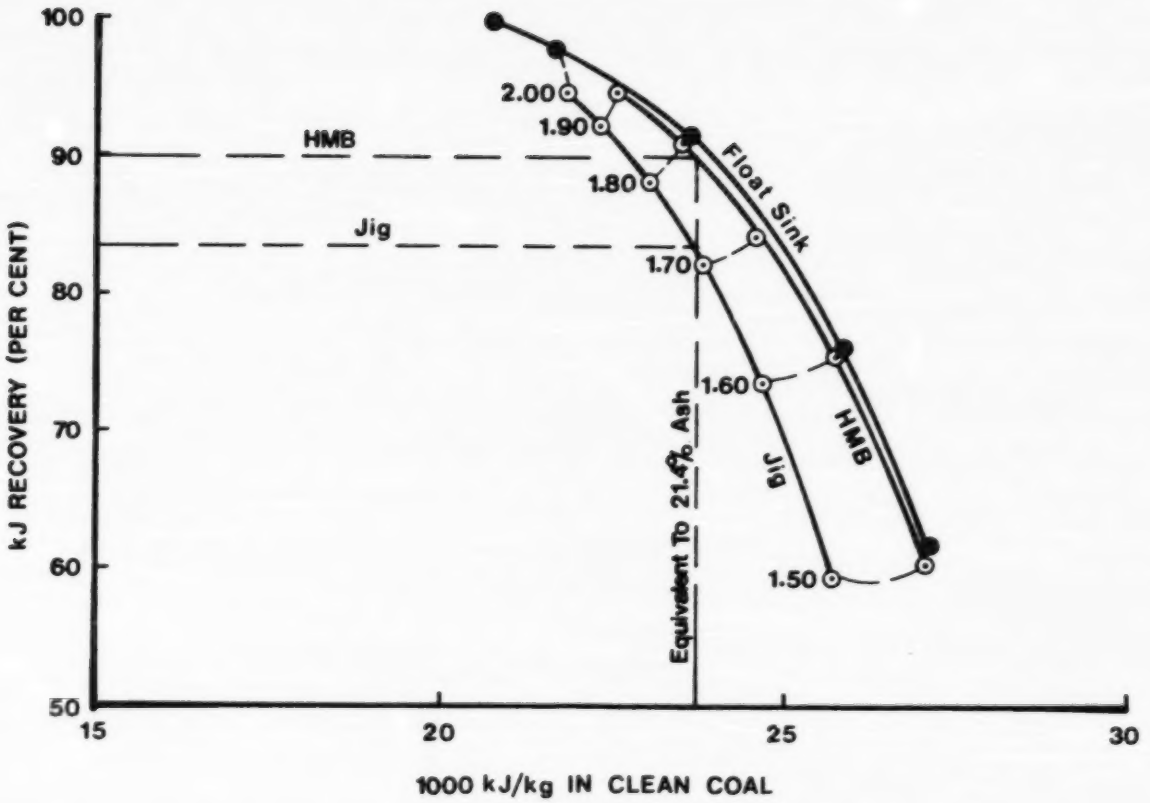

Fig. 14 - Thermal recovery prediction

APPENDIX A

WASHABILITY DATA AND ASH-kJ RELATIONSHIP

Table A-1 Washing characteristics of Wapiti coal 50 x 25.4 mm (12.29% of total)

Relative Density	Elementary data			Cumulative data					
				Float			Sink		
	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg
Float - 1.30	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
1.30 - 1.35	1.50	7.73	28755	1.50	7.73	28755	100.00	41.38	16385
1.35 - 1.40	7.51	11.48	27377	9.01	10.86	27606	98.50	41.89	16197
1.40 - 1.45	13.91	17.24	25260	22.92	14.73	26182	90.99	44.40	15274
1.45 - 1.50	8.31	21.10	23841	31.23	16.43	25559	77.08	49.31	13472
1.50 - 1.60	11.16	28.39	21161	42.39	19.58	24401	68.77	52.71	12219
1.60 - 1.80	20.55	44.73	15154	62.94	27.79	21382	57.61	57.43	10487
1.80 - 2.00	23.66	60.65	9302	86.60	36.77	18082	37.06	64.47	7900
2.00 - 2.17	9.13	68.70	6343	95.73	39.81	16962	13.40	71.20	5423
2.17 - Sink	4.27	76.55	3457	100.00	41.38	16385	4.27	76.55	3457

Table A-2 Washing characteristics of Wapiti coal 25.4 x 12.7 mm (16.56% of total)

Relative Density	Elementary data			Cumulative data					
				Float			Sink		
	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg
Float - 1.30	0.20	5.13	29711	0.20	5.13	29711	100.00	36.15	18309
1.30 - 1.35	4.21	7.21	28947	4.41	7.12	28982	99.80	36.21	18286
1.35 - 1.40	10.98	10.95	27572	15.39	9.85	27976	95.59	37.49	17817
1.40 - 1.45	13.20	16.02	25708	28.59	12.70	26929	84.61	40.93	16551
1.45 - 1.50	8.82	21.33	23756	37.41	14.73	26181	71.41	45.53	14858
1.50 - 1.60	13.24	28.91	20970	50.65	18.44	24819	62.59	48.95	13605
1.60 - 1.80	23.57	42.70	15900	74.22	26.14	21986	49.35	54.32	11629
1.80 - 2.00	15.81	60.69	9287	90.03	32.21	19756	25.78	64.94	7723
2.00 - 2.17	6.61	67.92	6630	96.64	34.65	18858	9.97	71.69	5244
2.17 - Sink	3.36	79.11	2516	100.00	36.15	18309	3.36	79.11	2516

Table A-3 Washing characteristics of Wapiti coal 12.7 x 2 mm (45.29% of total)

Relative Density	Elementary data			Cumulative data					
				Float			Sink		
	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg
Float - 1.30	5.74	4.33	30005	5.74	4.33	30005	100.00	26.22	21958
1.30 - 1.35	9.12	6.63	29160	14.86	5.74	29486	94.26	27.55	21468
1.35 - 1.40	14.24	9.35	28160	29.10	7.51	28837	85.14	29.80	20644
1.40 - 1.45	12.53	12.95	26837	41.63	9.15	28235	70.90	33.90	19135
1.45 - 1.50	11.77	17.65	25109	53.40	11.02	27546	58.37	38.40	17482
1.50 - 1.60	13.86	26.04	22025	67.26	14.12	26408	46.60	43.64	15555
1.60 - 1.80	16.66	40.02	16886	83.92	19.26	24518	32.74	51.09	12816
1.80 - 2.00	9.35	55.67	11133	93.27	22.91	23176	16.08	62.56	8600
2.00 - 2.17	4.28	67.41	6817	97.55	24.86	22458	6.73	72.14	5080
2.17 - Sink	2.45	80.39	2046	100.00	26.22	21958	2.45	80.39	2046

Table A-4 Washing characteristics of Wapiti coal 2 x 0.6 mm (15.19% of total)

Relative Density	Elementary data			Cumulative data					
				Float			Sink		
	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg
Float - 1.30	10.62	3.30	30384	10.62	3.30	30384	100.00	17.40	25200
1.30 - 1.35	9.18	5.89	29432	19.80	4.50	29943	89.38	19.08	24584
1.35 - 1.40	22.25	8.18	28590	42.05	6.45	29227	80.20	20.59	24030
1.40 - 1.45	19.36	10.76	27642	61.41	7.81	28727	57.95	25.35	22279
1.45 - 1.50	11.21	16.07	25690	72.62	9.08	28258	38.59	32.67	19588
1.50 - 1.60	10.23	23.57	22933	82.85	10.87	27601	27.38	39.47	17090
1.60 - 1.80	9.09	36.60	18143	91.94	13.42	26666	17.15	48.95	13604
1.80 - 2.00	4.17	53.48	11938	96.11	15.15	26027	8.06	62.87	8485
2.00 - 2.17	1.74	65.31	7589	97.85	16.05	25699	3.89	72.94	4783
2.17 - Sink	2.15	79.12	2512	100.00	17.40	25200	2.15	79.12	2512

Table A-5 Washing characteristics of Wapiti coal 0.6 x 0.15 mm (7.21% of total)

Relative Density	Elementary data			Cumulative data					
				Float			Sink		
	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg
Float - 1.30	2.01	2.99	30498	2.01	2.99	30498	100.00	18.38	24880
1.30 - 1.35	10.88	3.91	30160	12.89	3.77	30213	97.99	18.69	24765
1.35 - 1.40	12.30	6.42	29237	25.19	5.06	29736	87.11	20.54	24091
1.40 - 1.45	23.26	8.13	28608	48.45	6.53	29195	74.81	22.86	23245
1.45 - 1.50	19.02	11.55	27351	67.47	7.95	28675	51.55	29.51	20825
1.50 - 1.60	10.94	19.48	24436	78.41	9.56	28083	32.53	40.01	17010
1.60 - 1.80	10.51	33.23	19382	88.92	12.36	27055	21.59	50.41	13247
1.80 - 2.00	4.84	48.72	13688	93.76	14.23	26365	11.08	66.72	7427
2.00 - 2.17	1.83	62.10	8767	95.59	15.15	26028	6.24	80.67	2571
2.17 - Sink	4.41	88.38	~ 0	100.00	18.38	24880	4.41	88.38	~ 0

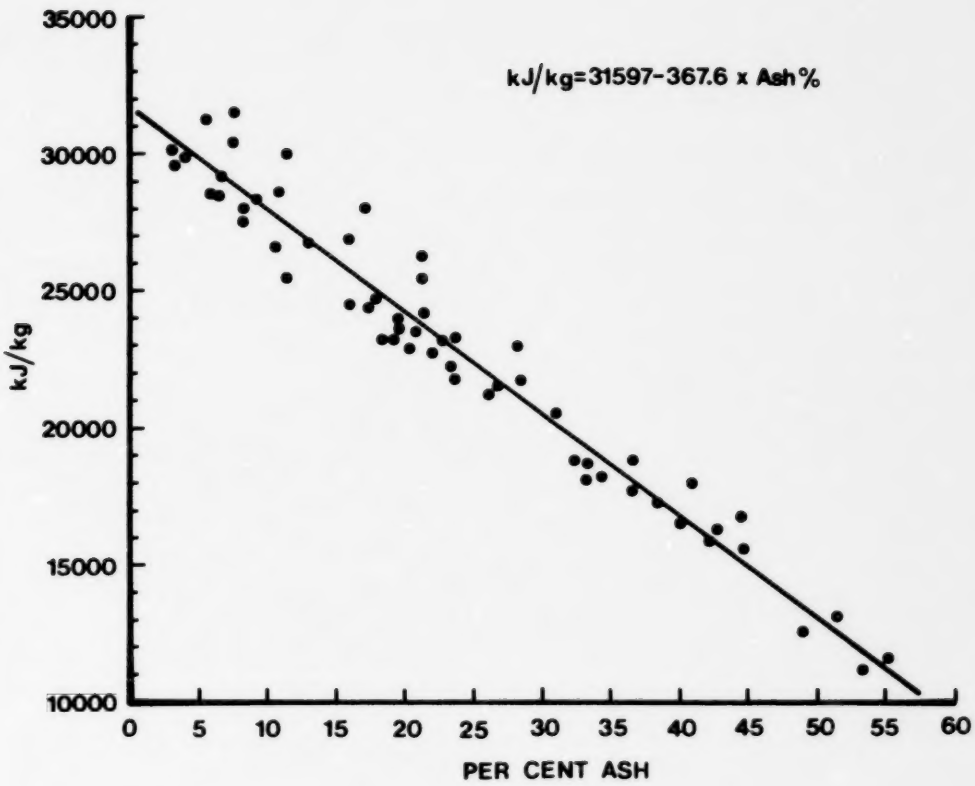

Fig. A-1 - Ash-kJ relationship of Wapiti coal